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A Comparison of Paving Brick Tests

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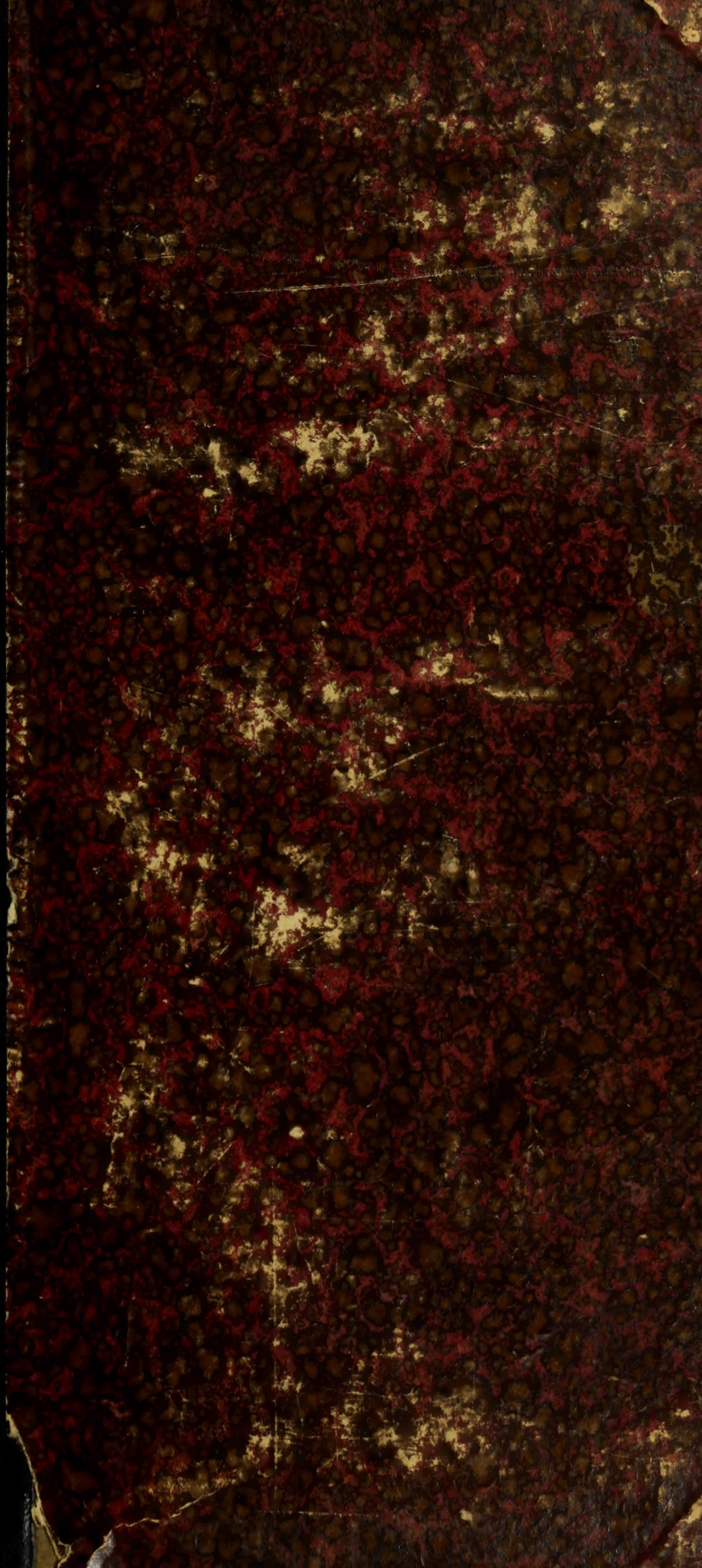

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A Comparison of Paving Brick Tests

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BY

JOHN BARR

THESIS FOR DEGREE OF BACHELOR OF SCIENCE

IN CIVIL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

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May 30, 1902

This is to certify that the thesis prepared under the direction of Professor Talbot by

JOHN BARR

entitled A COMPARISON OF PAVING BRICK TESTS

is approved by me as fulfilling this part of the requirements for the Degree of Bachelor of Science in Civil Engineeering.

Ira O. Baker.

Head of Department of Civil Engineering

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Just after title page.

TALBOT-JONES RATTLER.

With Veedersburg Block.

Before Rattling.

After Rattling.

A Comparison of Paving Brick Tests.

There are four principal tests which may be applied to brick to determine their fitness for paving material, viz: crushing, cross-breaking, absorption and abrasion and impact. The first has been decreed by many authorities to be too elaborate and expensive for practical application and will not be discussed here. The remaining three are more commonly used, each to detect a different property in the brick. The action of frost on brick depends largely upon the amount of water therein. The cross-breaking test reveals the inner structure, homogeneity, fineness of grain etc, and detects flaws. The rattler test acts by abrasion and by impact and indicates the property of the brick to resist these forces.

If these properties were of equal

importance in determining the quality of the brick ideal tests would all give the same rating to different makes and grades of brick tested. Many experiments have been made to determine whether or not this condition exists among the tests usually made and it has been found that in general it does not.

In comparing the absorption and rattler tests, for instance, we find that a tough, coarse-grained brick suffers in the rattler from abrasion, and a hard, fine-grained brick suffers from impact. The amount of the loss may be nearly the same in the two cases and yet the amount of water absorbed will differ widely. Again, in comparing two grades of the same make of brick we find that over-burned samples lose even more in the rattler than the soft ones while they give a much lower absorption test.

Prof. A. Marston of Iowa State College has made a quite complete set of experiments in this direction

A description of them appears in the Proceedings of the Iowa Engineering Society 1899. Prof. W. K. Hatt of Purdue University also draws attention to this feature of brick testing in an article before the Indiana Engineering Society of the same year. Both articles are accompanied by diagrams which show very clearly the discrepancy existing among the results of the various tests.

As the three tests do not agree, most engineers accept the theory that the rattler most closely represents the actual conditions in the street and this test has become the chief one, and has been standardized by the National Brick Manufacturers Association. In the experiments made for this association different makes of brick were used, large numbers being treated and a general average taken without paying much attention to the individual specimens. That such attention to individual brick should be given is true without doubt. Some one has said

that at the greatest defect in paving brick today is the lack of uniformity in the product from the same manufacturer. Uniformity is the first virtue to be demanded in a brick pavement.

In the hope of shedding some light on the question of the relation existing between the different tests and incidentally to note the uniformity of the results the writer undertook a series of experiments in which each of the three tests was performed upon the same individual brick, a process which to his knowledge, has not been followed before. It was hoped that by first rattling the brick, then cross-breaking it, and finally soaking it in water, and by repeating this with a large number of brick of the same make, a direct relation between the three tests could be detected, as the results would not be affected by such varying factors as kind and quality of the material, process of mixing and burning. With what success this was done will be shown later.

In making the experiments

three makes of Indiana brick were used, viz: Clinton, Veedersburg (Poston) and Terre Haute. The Clinton and Veedersburg were block size measuring $3\frac{3}{8}" \times 4" \times 9\frac{1}{4}"$, the latter being perhaps a trifle shorter than the former. They are made from shale and are side cut and repressed. The Terre Haute brick measured $2\frac{1}{2}" \times 4" \times 8\frac{7}{8}"$, are made of shale and are side cut but not repressed (except the hardest grade).

Each make was divided into different grades, - soft, medium, and overburned. Only two grades were made of the Veedersburg block, no over-burned ones being obtained. Two grades of Danville, Illinois brick were also tested. They were really different makes consisting of different material. One was much softer and coarser-grained than the other.

The grading was done by eye alone depending on the color as a guide, but it is quite certain that the soft and over-burned grades of the Clinton and Terre Haute makes would

have been rejected by a pavement inspector. It may be stated that grading by color alone is often misleading, especially as between the medium and over-burned varieties. A brick appears, perhaps, very much over-burned, being quite cindery on the surface. This may be due to one of two reasons, either the brick really is over-burned and is cindery throughout or it is merely fire-flashed, the defect being on the surface only. In the first case the brick is, without doubt, of poor quality, but in the second it may be one of the strongest brick of the whole lot. That such mistakes were made appeared in the rattler test.

Description of Tests.

The Rattler Test. — In making this test the N. B. W. A. Standard Rattler was not used much, the Talbot-Jones type being much better adapted to this particular work. In this rattler the brick are clamped about the circumference of an iron drum and

present a surface much like that of a pavement, upon which the shot slide, roll and fall as the machine revolves.

The accompanying photographs show the details quite clearly. One was taken just after placing the brick in position while the other shows the same set of brick after rattling. But one edge of the brick is worn and the individual brick are easily marked and identified afterwards. For a fuller description and sketches of the machine see the thesis of C. W. Malcolm, '02.

Prof. Orton of Ohio made many experiments with this machine to determine the best charge of shot; the effect of various charges on the amount of wear, the effect of different spacing of the brick, of different speeds, duration of test etc., and recommended the following standard: charge to consist of 60# of $2\frac{3}{8}$" cast iron cubes and 90# of $1\frac{1}{2}$" cast iron cubes, speed 41 R. P. M., length of test 3000 revolutions, spacing one inch. These conditions (with one exception to be noted) were adopted by the writer

for the first experiments made, but the resulting wear on the Clinton block of the soft and over-burned grades was such that the block were not suitable for cross-breaking afterwards. A decided chipping occurred which broke down the edges of the block quite badly. The conditions were therefore changed and 150# of the smaller shot was used for the charge, the speed was reduced to 30 R.P.M. and the length of test kept as before. A spacing of about ¼" between bricks was used in all tests instead of the wider spacing suggested by Prof. Orton. The appealing feature of this rattler is the arrangement of the brick and the closer the spacing the greater is this resemblance to the pavement. The wider spacing also gives more chance for chipping which has already been said to be great — perhaps too much so. Under these new conditions the loss was much less and nearly all abrasion, being distributed more evenly over the face of the block. The test was conducted in this manner for all the brick which

were afterward cross-broken but for these only.

The fact that the greatest wear occurs at the speed of 41 R. P. M. was easily explained by observing the action of the shot during a test. Many of the shot are carried to the top of the rattler and fall across a diameter, thus delivering the maximum blow possible, for at a less speed they would not be carried so high and at a greater speed they would be carried clear over.

The Absorption Test — This was made quite simply. The individual brick were weighed, then placed in water to remain 48 hrs., after which they were removed, wiped dry with a cloth and weighed again. All of the brick used were either rattled, or cross-broken or both.

The scales used were Fairbanks balances graduated to tenths of grams but it was found that a whole block was a decided overload and the reading could not be considered accurate

closer than one gram and preferably two or three. Under the bats of the cross-broken brick the scales worked much better.

The brick were not dried especially for this test but as they had been under cover in a steam heated room for several months, it can safely be assumed that they were uniformly dry. The absolute results may therefore be considered somewhat low, but the relative results as correct.

The Cross-breaking Test:- These tests were made on a Philadelphia Machine Tool Co. testing machine of 100000# capacity. The brick were broken edgewise, a span of six inches being used. The knife edges were of cast-iron and of the form shown in the sketch (next page). They were four inches long and the bearing edges were rounded to a twelve-inch radius. It will be seen that the bottom of the knife edge is rounded transversely. This

facilitates somewhat the adjustment of the brick in the machine and gives a somewhat better bearing, but under a heavy load, say 12000#, the knife edges are thrown several feet when the break occurs.

The writer suggests that it would be better to round the bottom longitudinally. The opposite edges of many brick are not truly parallel and a square bearing cannot be obtained, the rounding of the bearing edge being insufficient. He also believes that much time could be saved by fastening the two lower knife edges together, thus preserving the constant span. Some little time

is necessary to carefully adjust each brick in the machine.

The upper knife edge was rigid.

Bearing plates were not used at first but were later, steel plates 1" x $\frac{1}{4}$" x 3$\frac{1}{2}$" being placed between each knife edge and the brick. This was more trouble but gave more uniform results, good square breaks being obtained in nearly every instance.

No attempt was made to determine the moment of inertia of the rattled brick as it was deemed unnecessary and inconsistent, considering the wide range of values of the breaking load, for brick apparently the same. Two sets of soft Clinton block were broken under the same conditions, bearing plates being used. One of these sets contained 15 new block. The other set contained 11 rattled block. The mean breaking load of the two sets was identical, 12,100#. This shows

conclusively that a small amount of wear from the upper side of the block affected the breaking load very little, if any.

Discussion of Results.

On page 26 is a tabular summary of the results of the tests made and Plate I gives a summary in the form of a diagram. This diagram shows clearly the relation existing among the various tests, several points of interest being distinctly brought out. The most evident, perhaps, is the failure of the absorption test to distinguish the overburned and brittle brick of the Clinton make. It will be seen that the soft grade is easily identified by both tests; that the medium grade has low rattler losses and is low in absorption; but that the overburned grade, while absorbing practically the same amount of water as the medium suffers even worse in the rattler than does the soft. In other words, up to a certain limit, say 2% absorption

for this particular make, the porosity of the brick does not change with the hardness and corresponding brittleness. The absorption test is valuable for detecting the soft brick but is useless for the other extreme of burning which is really the greater fault. This conclusion is verified by the tests of the Terre Haute brick and is probably true for the different grades of any make.

A study of just what the maximum absorption limit should be for each make of brick likely to be used in a given locality would be both interesting and valuable. See the recommendations of Prof. A. N. Talbot in the Report of the Illinois Society of Engineers and Surveyors, 1901.

Six sets of Veedersburg (Poston) block were thus tested for absorption and in the rattler. The first two sets were new block; the others were taken from the pavement on Taylor and Walnut streets, Champaign, having been under traffic for three years. The traffic on Taylor street was materially

heavier than that on Walnut street. Two grades were selected: medium and soft for the new block; good and poor, according to the wear for those from the street. The agreement of the two tests in rating the six sets is exceedingly close. It is also notable that in each case those block which had worn the better in the pavement, gave the better results in the tests.

A second point of interest is a comparison of the three tests, - cross-breaking, rattler and absorption, upon the medium grades of the four makes, Clinton, Terre Haute, Veedersburg and Danville. The following table shows the rating or rank of these brick by the several methods of testing.

Rank	Standard	Talbot-Jones	Absorption	Cr.-Breaking
1.	Danville	Clinton	Danville	———
2.	Clinton	Veedersburg	Terre Haute	Terre Haute
3.	Veedersburg	Terre Haute	Clinton	Clinton
4.	Terre Haute	Danville	Veedersburg	Veedersburg

It will be seen that the two rattlers agree with each other, with the exception of

the Danville brick, but disagree with the absorption and cross-breaking tests which also agree with each other. A cross-breaking test of the Danville brick was not obtained but from the appearance of the fracture the writer is confident that it would rank first in this test as it does in the absorption test. The fracture shows a very smooth, close grained structure and complete vitrification, which indicate a high modulus of rupture. The discrepancy in the results of the two rattlers in this case may be due to the fact that these brick are quite thin and therefore present a much larger proportion of edges to the action of the shot than is true with the block size. This opinion is confirmed by the comparatively great loss of the Terre Haute brick in the Talbot-Jones rattler. However, it is generally granted that the standard rattler also favors the block size, to the extent of about 2% for this grade of brick. See Mr. Malcolm's thesis for a fuller discussion of this point.

With the Talbot-Jones rattler it

was found possible to obtain two independent tests on the same brick by simply placing one edge up and then the other. Plates II, III and IV are the plotted results of such tests. They show that when considering the average loss of all the brick the two results check closely but when considering the losses suffered by the individual brick wide differences frequently occur, and seldom indeed did the brick suffer identical amounts each time. In some instances this difference is easily explained. On examination it was found that not infrequently one edge of a brick had transverse bumps or raised portions upon it where it had not rested on other bricks in the kiln. These raised portions were usually soft and wore down rapidly, hollow spots being found after rattling, where the bumps had been. The other edge of the brick being in good condition the amount of loss was quite different. In other cases one edge of the brick was really burned harder than the other. This however will explain only a few of the discrepancies and the others must be charged

to accidents in the rattler.

This fact has an important bearing on the comparison of the rattler and absorption tests of individual brick, for with such a large factor of accident it cannot be expected that a close agreement can be shown with units so small. This was found by the writer to be true of his experiments. Plate IV is a comparison of two rattler tests of medium Terre Haute brick, Plate V is a comparison of the rattler and absorption tests of the same brick, the mean of the two rattler tests being plotted. Plate VI is a like comparison except that the bricks were first graded according to the absorption test and that rattler loss was chosen for the side of the brick which more closely agreed with the absorption gain. In Plate V the general slope of the two lines was not the same, except for the middle third. In Plate VI the general slope is the same but the agreement cannot be said to be close.

Plates VII to XII incl. are comparisons of absorption and rattler tests, the brick in each case being graded accord-

ing to the rattler. Plates VII and VIII are comparisons of soft brick and the two lines agree closely in general slope. The other plates deal with the medium and hard grades and the agreement though still existing is not so evident. This emphasizes the point made before that beyond a certain limit the absorption test does not measure the hardness and brittleness of a brick.

Plates XIII and XIV are comparisons of the cross-breaking and absorption tests. No general agreement can be noted.

A cross-breaking test of the three grades of Clinton block was made, five samples of each grade being broken. The result of this test was as follows:

Grade	Breaking load	Absorp.
Soft	9520#	4.5%
Medium	9900	2.75
Hard	9660	.75

No bearing plates were used and out of the 15 samples 7 end breaks occurred, i.e. the breaks started at one

of the lower knife edges. The medium block seem to have been softer than the average of that grade, and the mean breaking load is distinctly lower than was obtained in other experiments. Under these circumstances the results appear somewhat unreliable. Taken as they are however, they show that the greatest cross-breaking strength is developed at that point of vitrification which gives the best rattler test, but that there is not a great deal of difference between the grades of this make. In the case of the Veedersburg block however, observations indicate that harder burning increases the modulus of rupture materially. In Plate XVI, Fig. 1, the results from twelve Veedersburg block are plotted. In nine cases out of the twelve the agreement between the cross-breaking and absorption lines is decidedly close.

Plates XV, XVI and XVII are comparisons of the three tests but show nothing that is not brought out by the other plates.

Conclusions.

In comparing the absorption and rattler tests of different grades of the same make it was shown conclusively that the porosity of the brick may not increase with the hardness after the most desirable degree of hardness is reached. and that the absorption test is incapable of detecting over-burned brick. It was also shown that the rattler does make the distinction quite clear.

The cross-breaking test seems to give both negative and positive indications. It was stated that Plates XIII and XIV failed to show any relation between the two tests, absorption and cross-breaking, as applied to individual brick. It must be noted, however, that in these cases the brick tested, Terre Haute and Clinton, both suffer in the rattler from chipping. On Plate XVI is a like comparison for Veedersburg block, which wear in the rattler more from abrasion than from impact, and in this case a much closer agreement is found. It was also found that the rating of the medium grades of Clinton, Terre Haute

and Veedersburg makes was the same by the two tests. This would indicate that tenacity (as shown by the cross-breaking test) and porosity (as shown by the absorption tests) are kindred properties. Certain it is that the smooth, fine grained, well vitrified brick absorb very little water and have high moduli of rupture. The writer believes that there is much room for further study on this point but wishes to emphasize the fact that great care must be exercised in breaking the samples, paying particular attention to knife edges, bearing plates etc. and examining each fracture for flaws.

As has been intimated, one of the striking features of the Talbot-Jones test, as herein used, is the chipping effect. This was most evident on the Terre Haute brick and yet the manufacturer claims that where a rigid cement filler is used no such chipping occurs under traffic. It was also noted in the case of the Veedersburg block taken from the pavement, where a rigid filler was not used, that much of

the wear was due to the breaking off of the edges down to a longitudinal groove on the side of the block intended to receive such filler. This brings out an interesting point. Would it not be well for city engineers to vary their rattler tests according to whether or not a rigid filler is specified? May not a rigid filler be of much more importance with some makes of brick than with others? With the Talbot-Jones rattler such variation is easily accomplished as the chipping effect decreases with the size of spaces, with the speed and with the amount of large shot used.

The chief object of commercial paving brick tests today is to compare different makes for their properties to bear up under traffic and to determine whether brick delivered on the street are up to grade. It has been held that porous bricks suffered from the action of frost and were also unsanitary, but as ordinarily good paving brick absorb little water, very little

attention is now paid to these points. In the light of this fact it would appear that the absorption test is unnecessary, since the rattler test is sufficient in itself to determine wearing properties, especially with the Talbot-Jones machine where the kind of wear is much more readily noted than in the standard process and the method of conducting the test may be varied to suit conditions. It is well known that many makes of paving brick which have stood well the test of traffic are high in absorption, and the writer believes that such brick lose by abrasion as distinct from impact. Also that brick having low absorption suffer from impact as distinct from abrasion and that this characteristic difference is fully brought out by the Talbot-Jones rattler. It would therefore seem that the absorption test may be discarded except as applied to pick out soft brick in a pavement during construction where it is certainly very convenient.

As for the cross-breaking test

it has been stated that it detects a property in the brick coexistant with porosity. It may therefore go with the absorption test, especially as very few brick in a street are actually broken in two.

Little can be said concerning the uniformity of the results. The diagrams show that in all cases quite large variations occur, but how much is due to the accident factor is a question. Plates II, III and IV show clearly that different makes of brick can be graded according to uniformity of scatter losses. The rating here is evidently Terre Haute, Clinton, Veedersburg; which differs from the rating according to amount of loss but agrees with that of the absorption and cross-breaking tests.

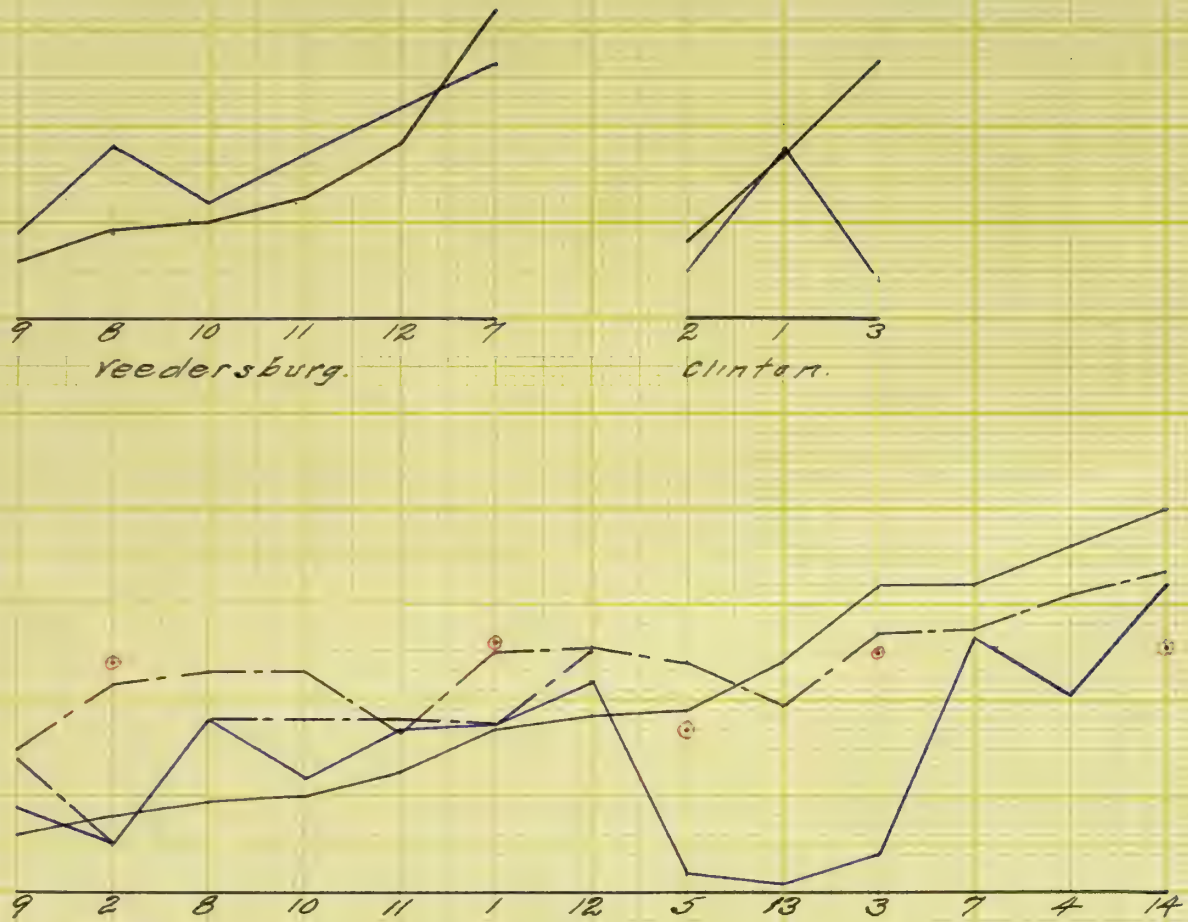
TABLE I.

Summary of Results

No.	Make	Grade	Rattler Standard	Rattler T. J.	Absorption		M. of Rupt.
1.	Clinton	Soft	25.12%	8.44%	4.4%		1930
2.		Med.	21.51	4.02	1.2		2090
3.		Hard	26.73	15.90	1.0		1970
4.	Terre Haute	Soft	31.45	18.08	5.1		
5.		Med.	24.20	9.40	.5		2990
6		Hard.	26.93		.56		
7.	Veedersburg	Soft	27.66	16.11	6.6		
8.	(New)	Med.	22.95	4.69	4.5 Stand.	T. J.	1450
9.	Veedersburg	Good	15.09	2.95	3.5	2.2	
10.	(Taylor St.)	Poor	23.26	4.99	4.5	3.9	
11.	Veedersburg	Good	16.60 (1)	6.23	4.5	4.2	
12.	(Walnut St.)	Poor	25.41	9.23	6.25	5.5	
13.	Danville, Ills.	Good	19.5	12.3	.3		
14.	.	Poor	33.6	20.1	7.7		1960

Conditions of T. J. rattler test: speed 42 R. P. M, charge, 60# of $2\frac{3}{8}$" cubes and 90# of $1\frac{1}{2}$" cubes, spacing, $\frac{1}{4}$" (26 each of Clinton and Veedersburg block, 33 Terre Haute brick and 37 Danville brick).

(1) Appears low, no explanation.



SUMMARY OF RESULTS.

Numbers refer to table.

PLATE I

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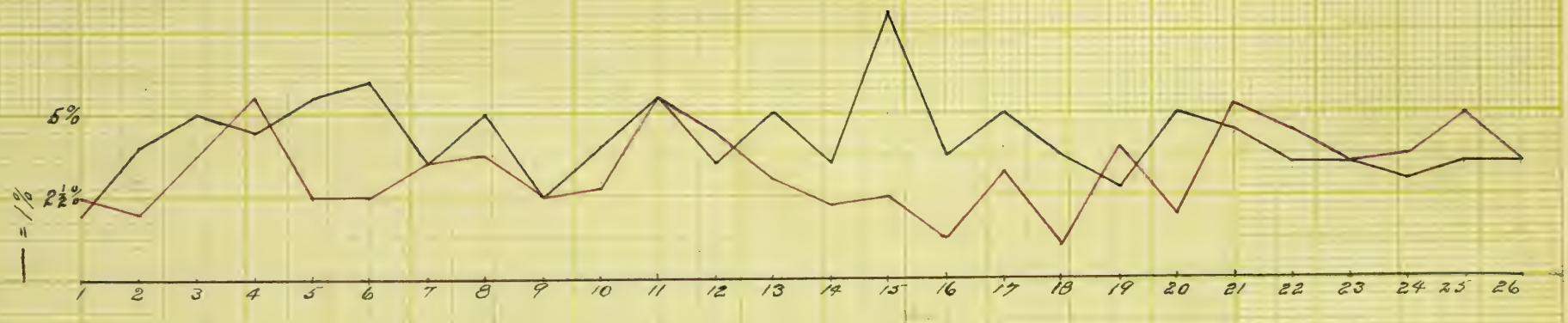
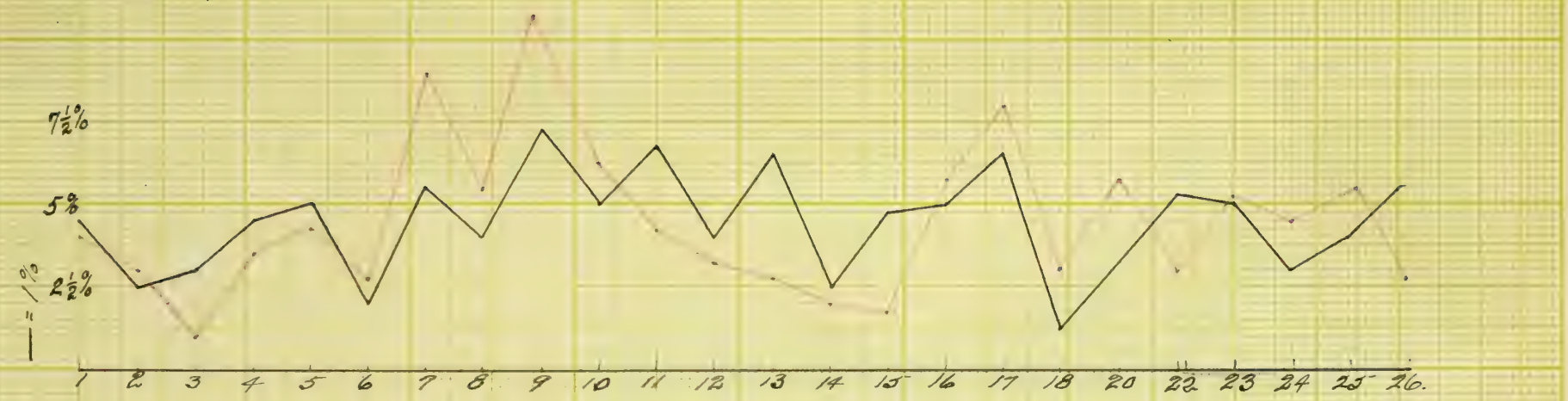


T.J. Rattler Tests of Medium Clinton Block.

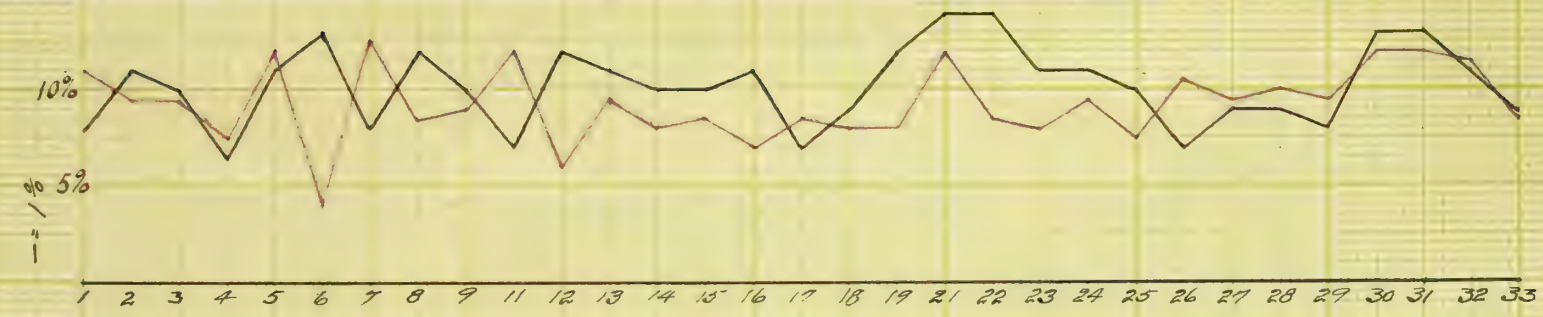
Black = one side, red = the other side of the same block.

PLATE II



Comparison of T.J. Rattler Tests of Medium Hard Veedersburg Block.
Black = one side, red = the other side of the same block.

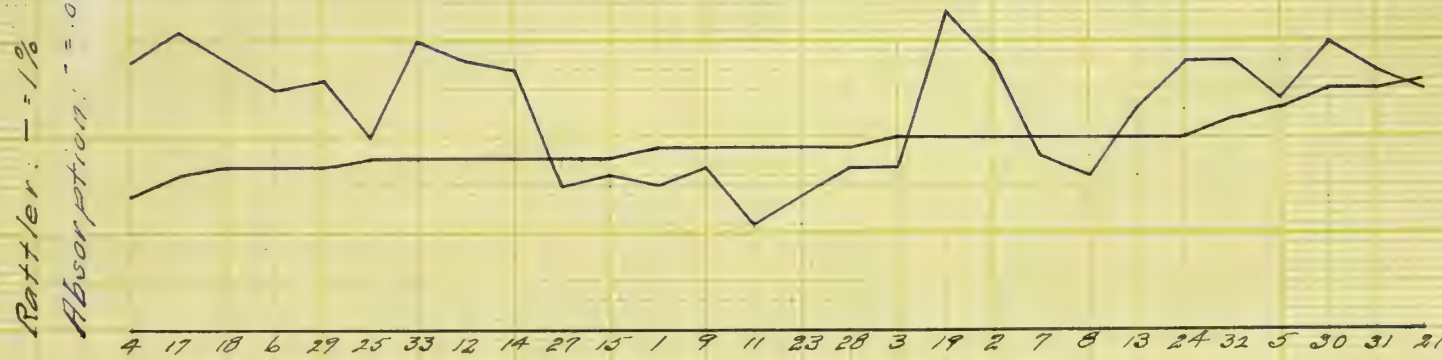
PLATE. III.



T.J. Rattler Tests of Medium Terre Haute Brick.
Black = one side, red = the other side of the same brick.

PLATE IV.

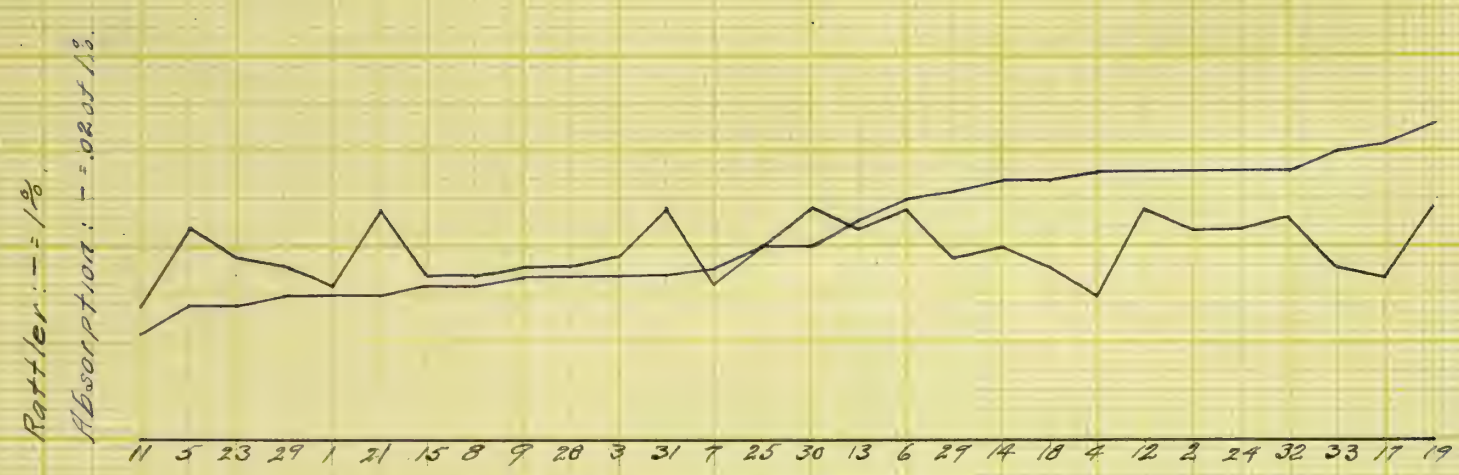
DIETZGEN CO., CHICAGO.



Comparison of T.J. Rattler and Absorption Tests
of
Medium Terre Haute Brick.

N.B. Rattler losses = mean of two tests.

PLATE V.



Comparison of T. J. Rattler and Absorption Tests
of
Medium Terre Haute Brick.

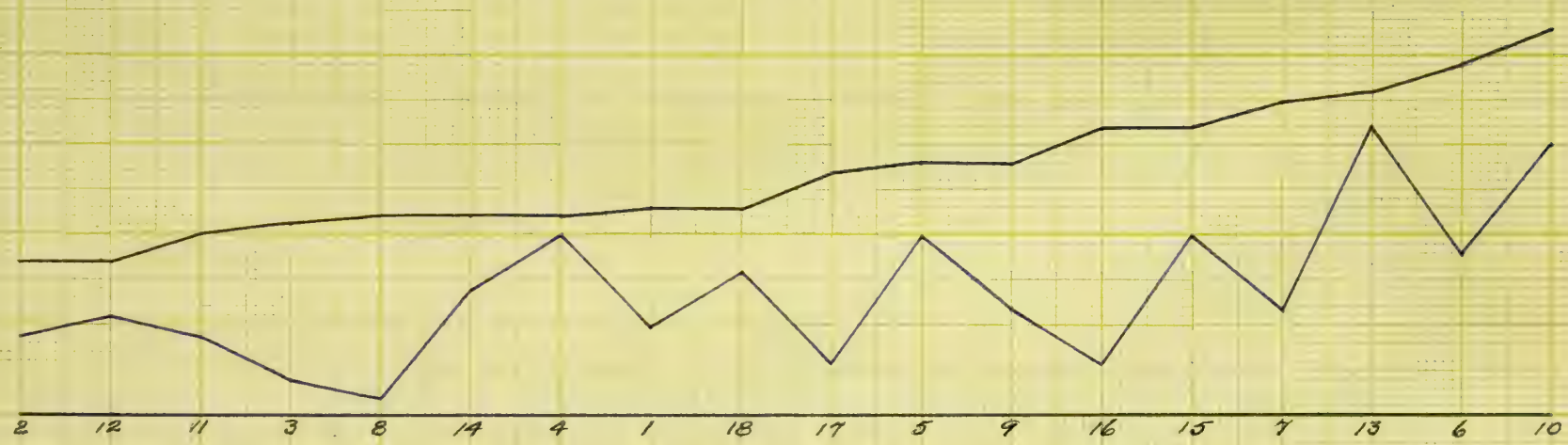
N.B. Rattler losses selected to agree with absorption gains.

PLATE VII.

Comparison of T.J. Rattler and Absorption Tests
of
Soft Terre Haute Brick.

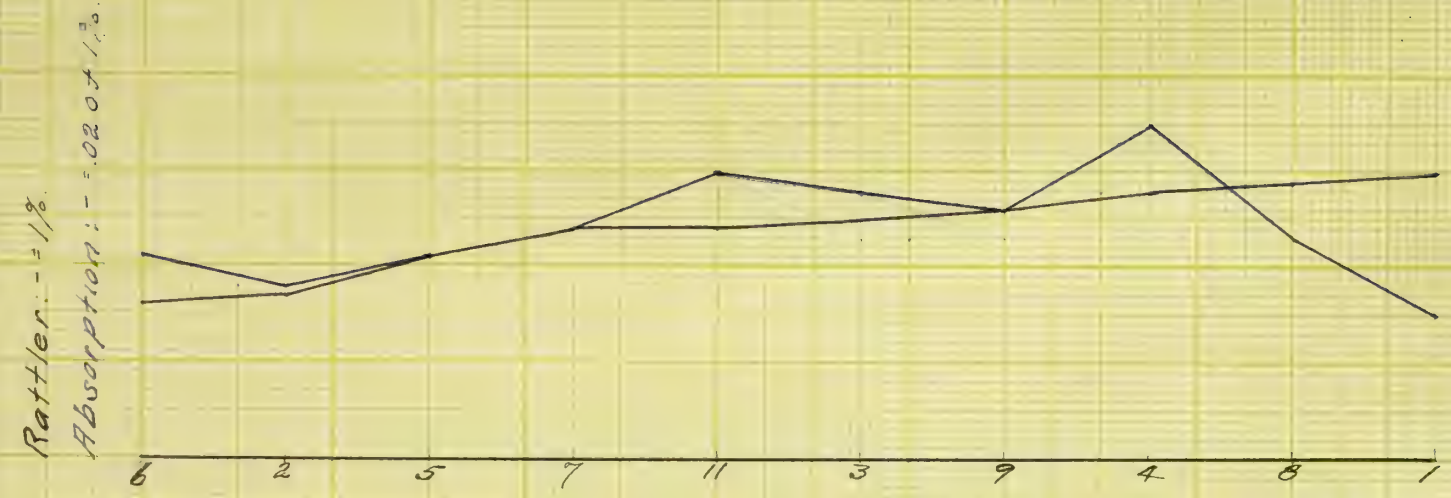
PLATE VII.

KEUFFEL & ESSER CO., CHICAGO.



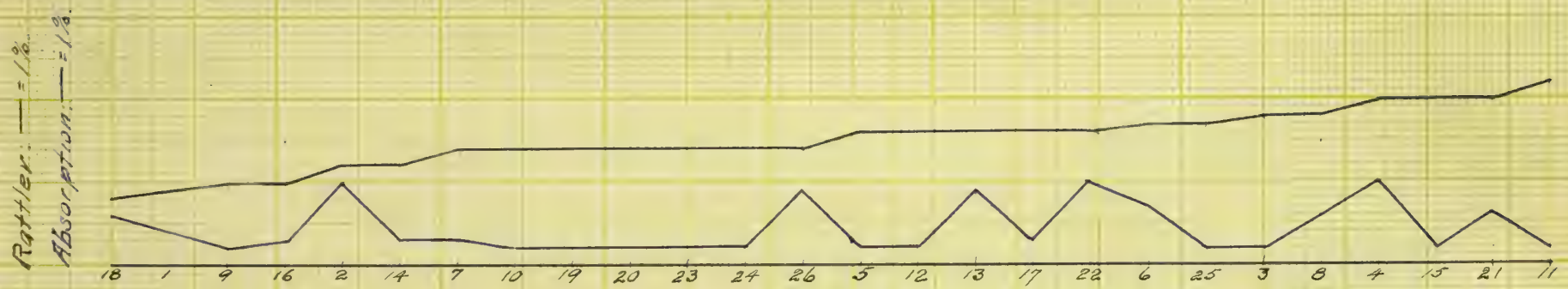
Comparison of Standard Rattler and Absorption Tests
of
Soft Terre Haute Brick.

PLATE VIII.



Comparison of Standard Rattler and Absorption Tests
of
Medium Terre Haute Brick.

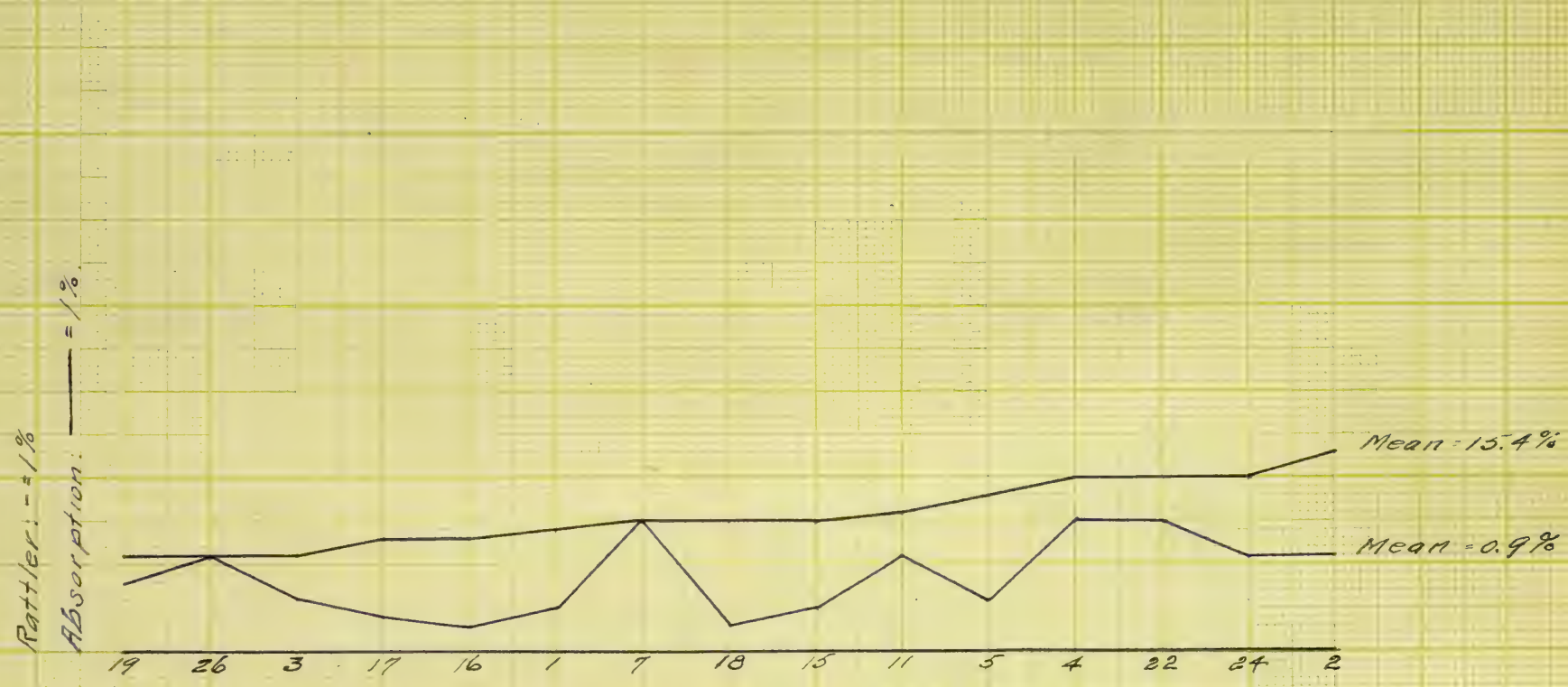
PLATE IX.



Comparison of T.J. Rattler and Absorption Tests,
of
Medium Clinton Block.

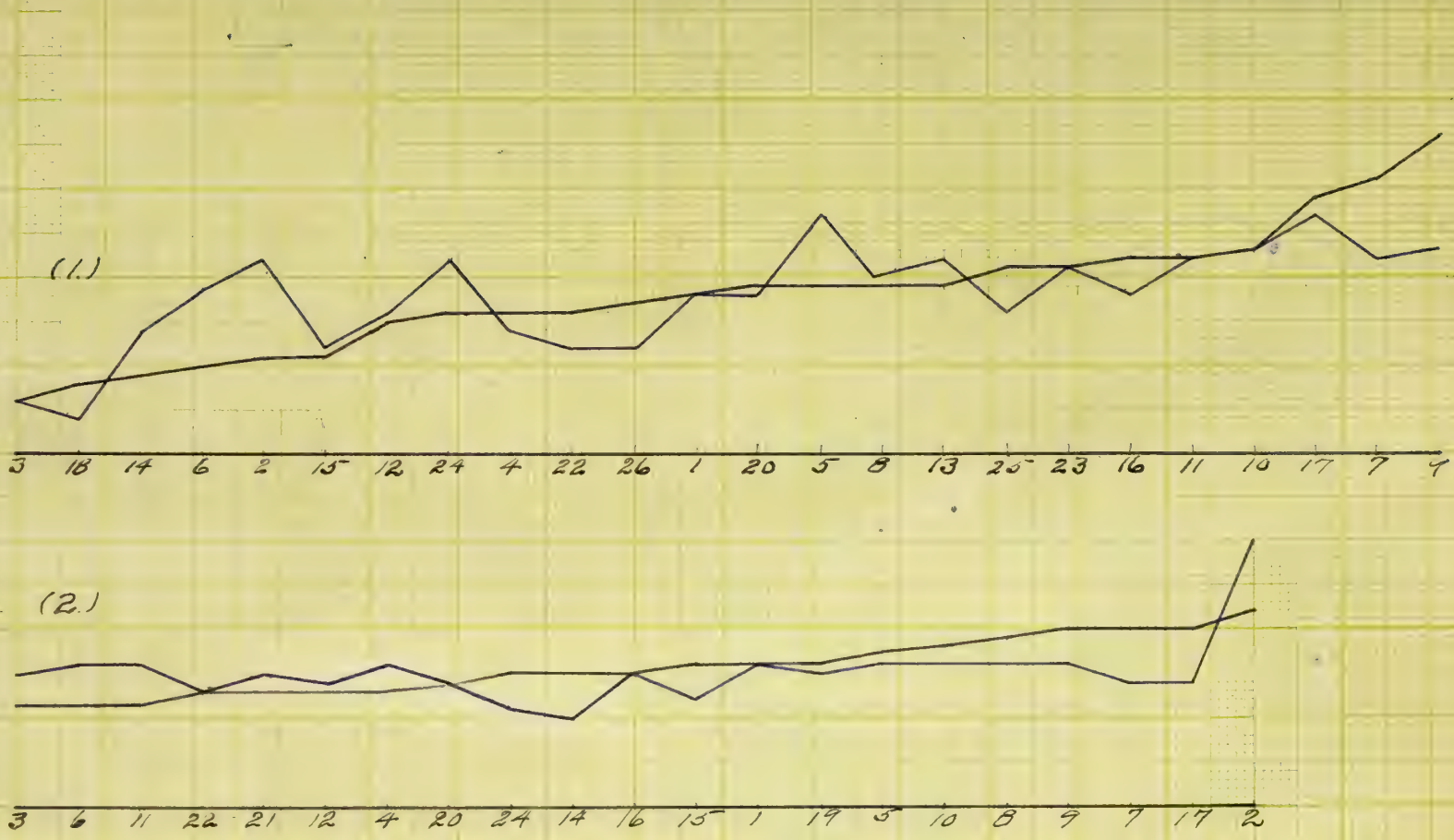
PLATE X

EUGENE DIETZGEN CO., CHICAGO.



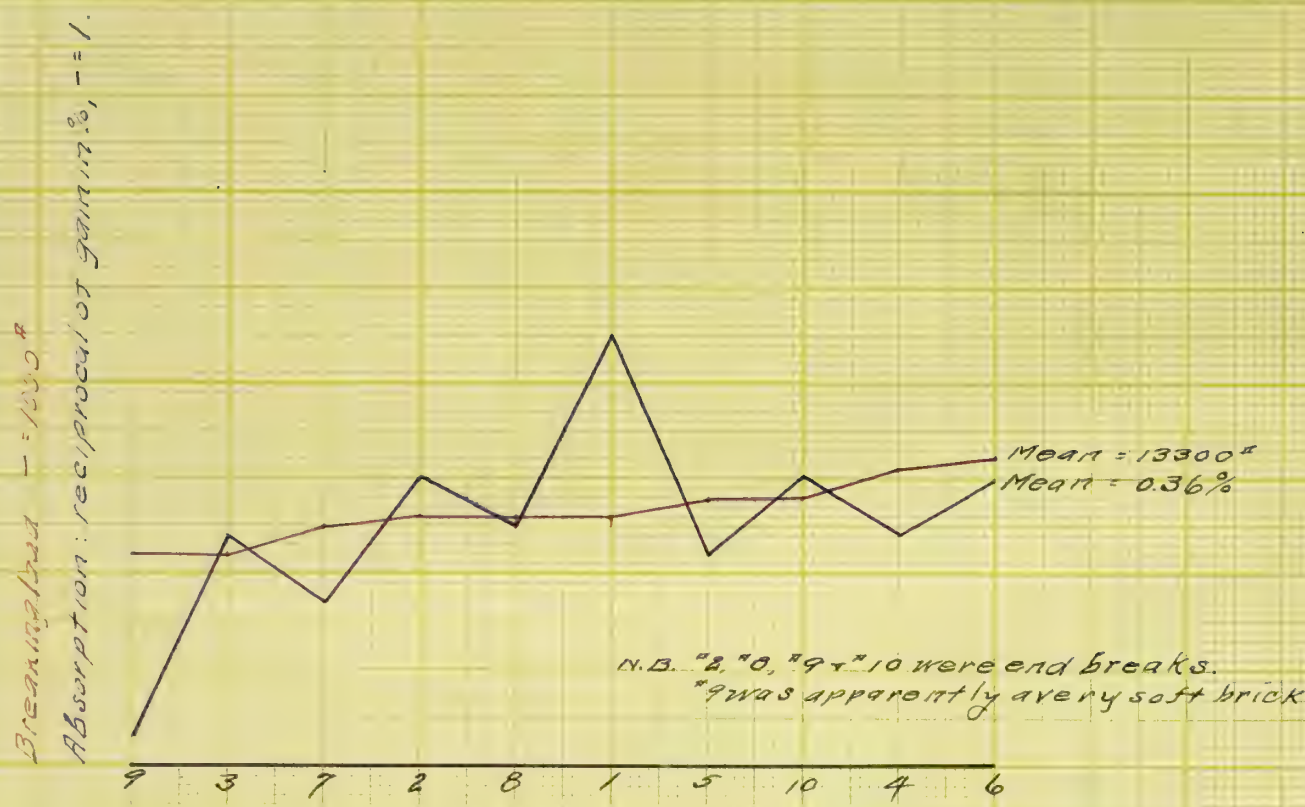
Comparison of T.J. Rattler and Absorption Tests
of
Very Hard Clinton Block.

PLATE XI.



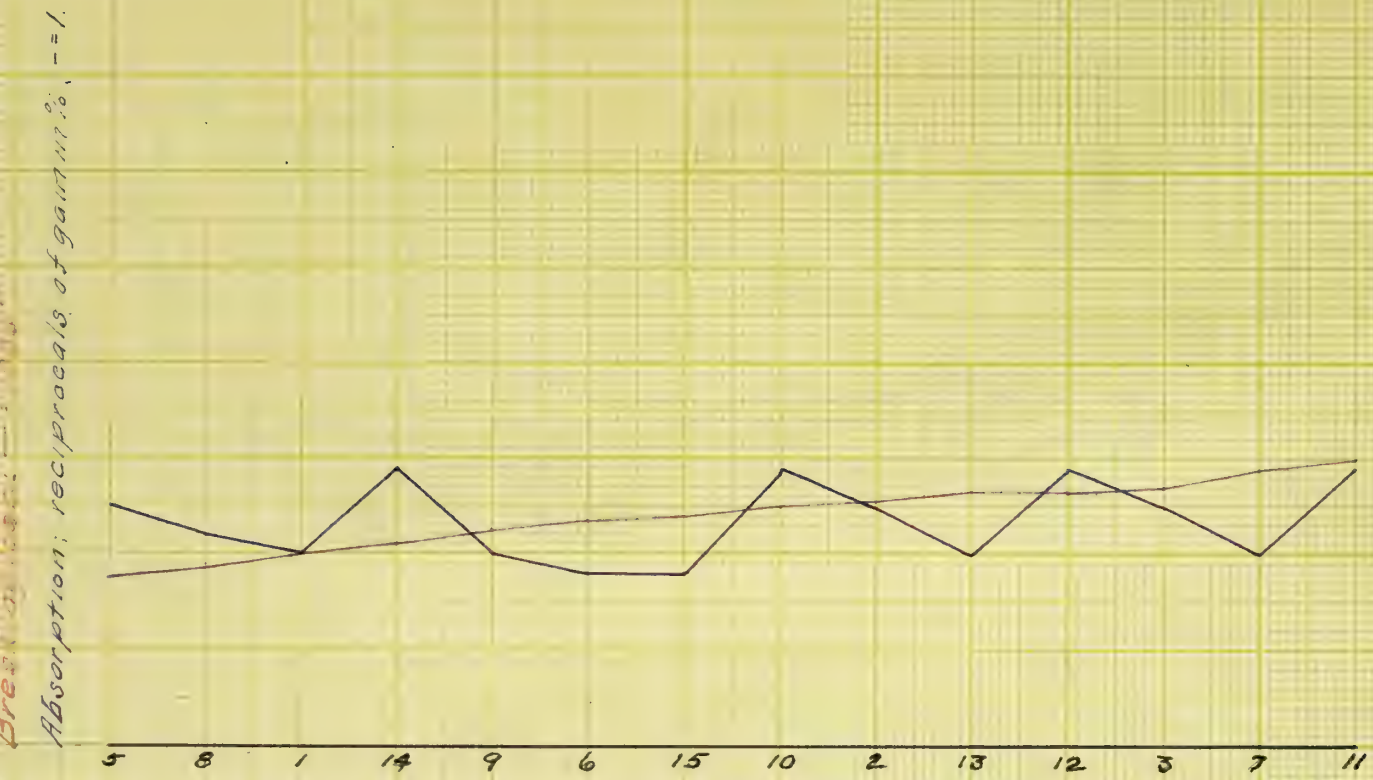
Comparison of T.J. Rattler and Absorption Tests
of
Veedersburg Block.
(1) Hard (Medium)
(2) Soft.

PLATE XII


Breaking load = 1/1000 #
Absorption: reciprocal of gain in %, - = 1.
Mean = 13300 #
Mean = 0.36%
N.B. "2, "8, "9 + "10 were end breaks.
"9 was apparently a very soft brick.
9 3 7 2 8 1 5 10 4 6

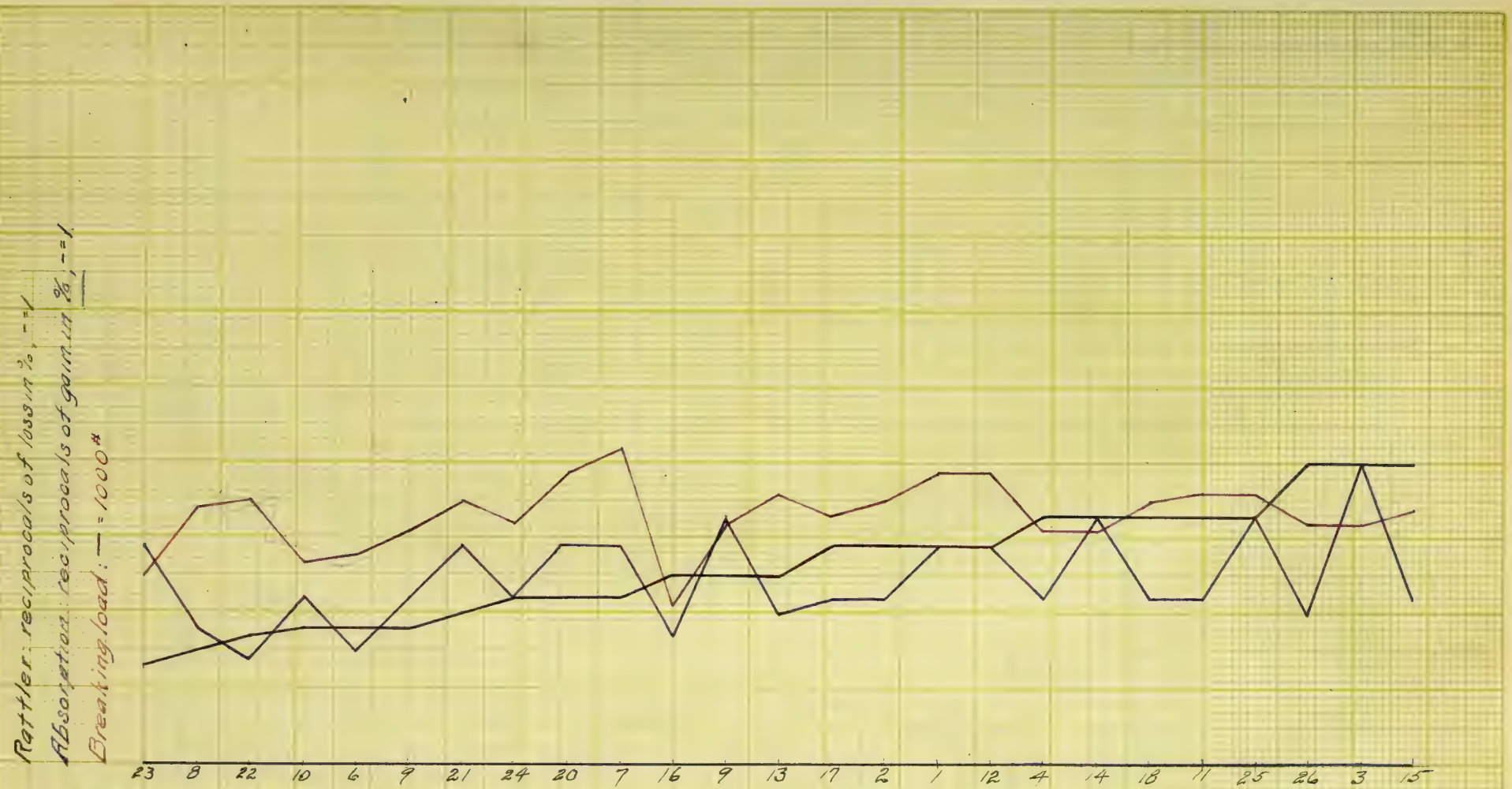
Comparison of Cross-breaking and Absorption Tests
of
Medium Terre Haute Brick.

PLATE XIII.



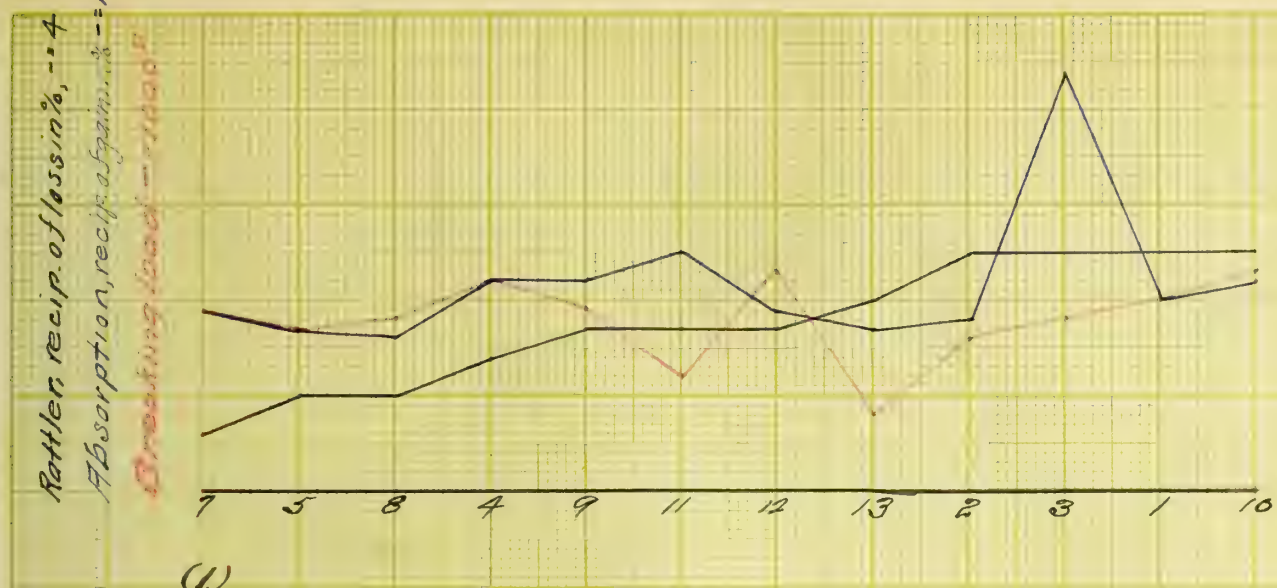
Comparison of Cross-breaking and Absorption Tests
of
Soft Clinton Block.

PLATE XIV.

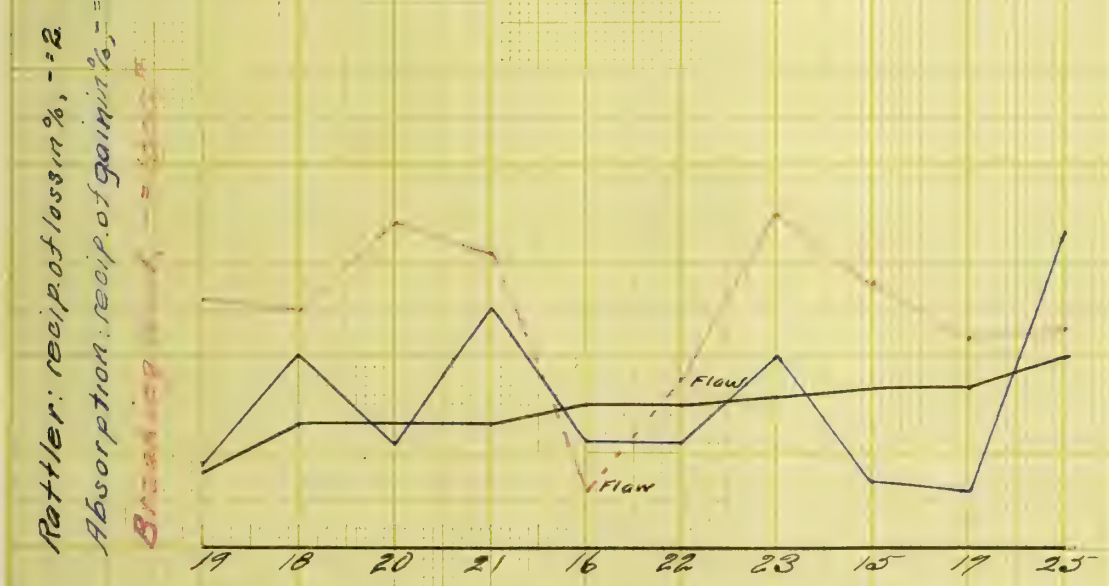

Rattler: reciprocals of loss in % = 1
Absorption: reciprocals of grm. in 1/2 = 1
Breaking load: — = 1000#
23 8 22 10 6 9 21 24 20 7 16 9 13 17 2 1 12 4 14 18 11 25 26 3 15

Comparison of T.J. Rattler, Cross Breaking and Absorption Tests
of
Soft Clinton Block.

PLATE XV.



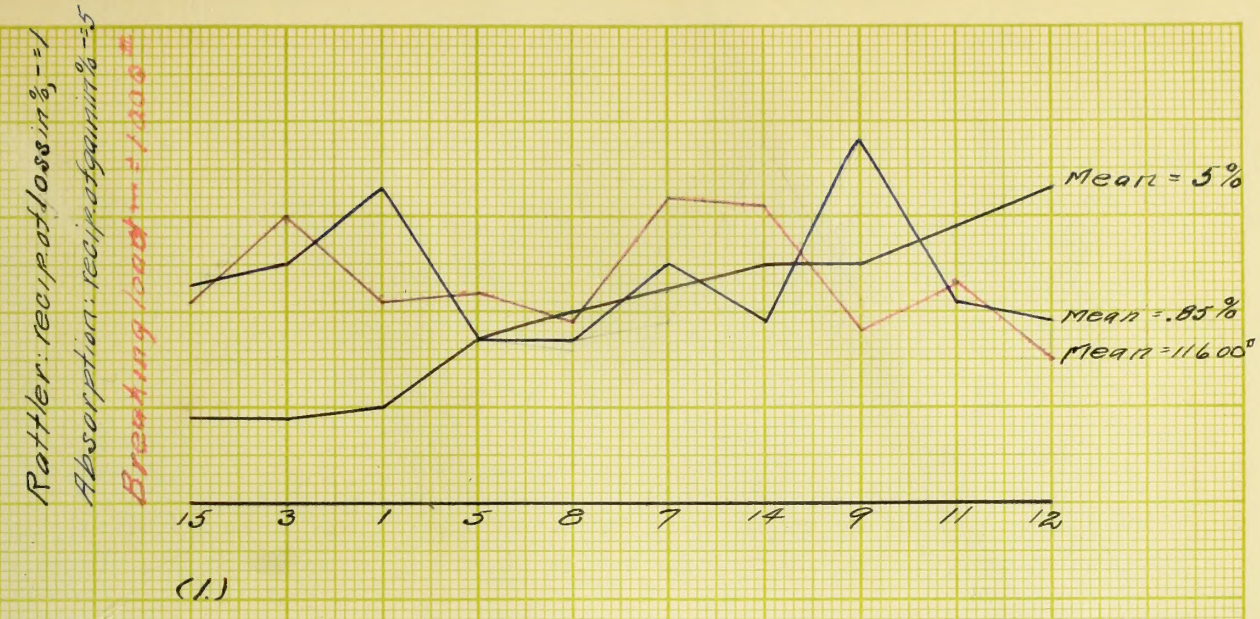
(1)



(2)

Comparison
of
T. J. Rattler. Cross-breaking and Absorption Tests.
of
Medium Block.
(1) Veedersburg.
(2) Clinton.

PLATE XVI.


Rattler: reciprocal loss in % = 1
Absorption: reciprocal of gain in % = 5
Breaking load = 1/1200 #
Mean = 5%
Mean = .85%
Mean = 11600#
15 3 1 5 8 7 14 9 11 12

(1.)

Rattler: reciprocal of loss in % = 1
Absorption: " gain in % = 1
Breaking load = 1000 #
Mean = 3½%
Mean = 3½%
Mean = 12000#
18 26 25 19 16 24 23 17 22 20

(2.)

Comparison
of
T.J. Rattler, Cross-breaking and Absorption Tests
of
Clinton Block.
(1) Over burned
(2) Soft.

PLATE XVII

EUGENE DIETZGEN CO., CHICAGO.